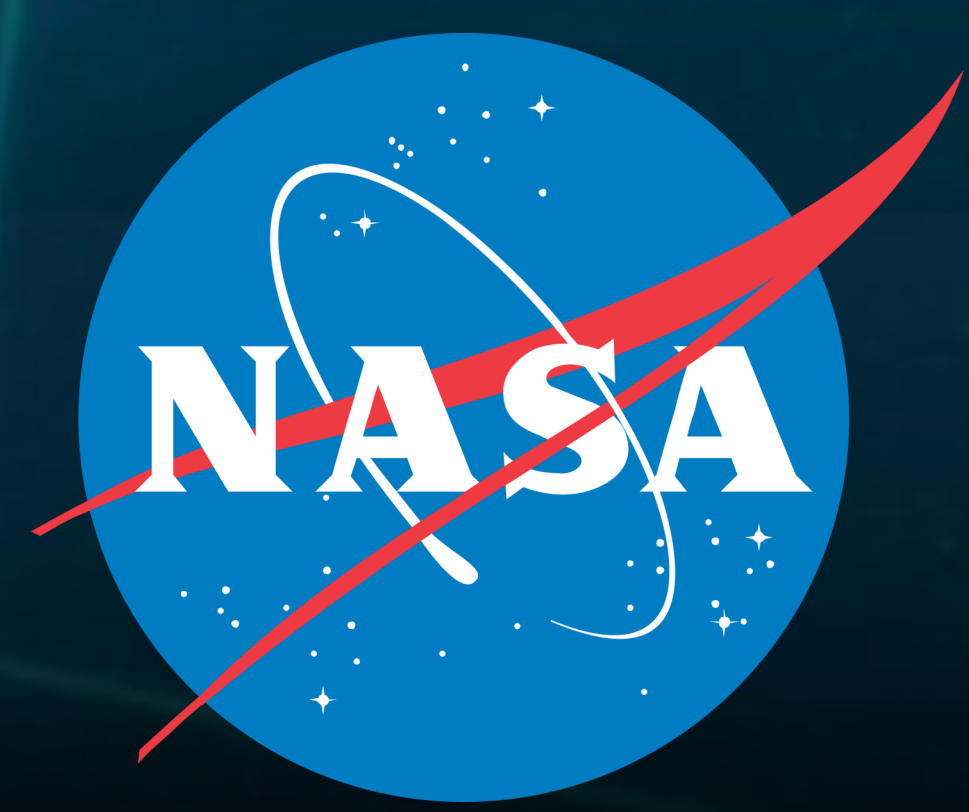




Z-2 Suit Support Stand & MKIII Suit Center of Gravity Test



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Z-2 Suit Support Stand

Introduction

NASA's next generation spacesuits are the Z-Series suits, made for a range of possible exploration missions in the near future. The prototype Z-1 suit has been developed and assembled to incorporate new technologies that has never been utilized before in the Apollo suits and the Extravehicular Mobility Unit (EMU). NASA engineers tested the Z-1 suit extensively in order to developed design requirements for the new Z-2 suit.

At the end of 2014, NASA will be receiving the new Z-2 suit to perform more testing and to further develop the new technologies of the suit. In order to do so, a suit support stand will be designed and fabricated to support the Z-2 suit during maintenance, sizing, and structural leakage testing. The Z-2 Suit Support Stand (Z2SSS) will be utilized for these purposes in the early testing stages of the Z-2 suit.

Design Parameters

Using Creo Parametric, the support stand is designed and fabricated using 80/20 Inc. t-slot profiles as the main support structure. T-slot framing is more versatile, efficient, and economical than welding. In addition, t-slotted frames are easily modified and disassembled to tailor to the user's needs. The design requirements of the Z-2 suit support stand are as follows:

- Support 2x the total weight of the Z-2 suit (340 lbs)
- No interference with umbilical routing
- Ability to attach & detach casters for transport and testing
- Accessibility to Z-2 suit components for test technicians
- Other features that will facilitate test technicians such as tool holders, push handles, etc.

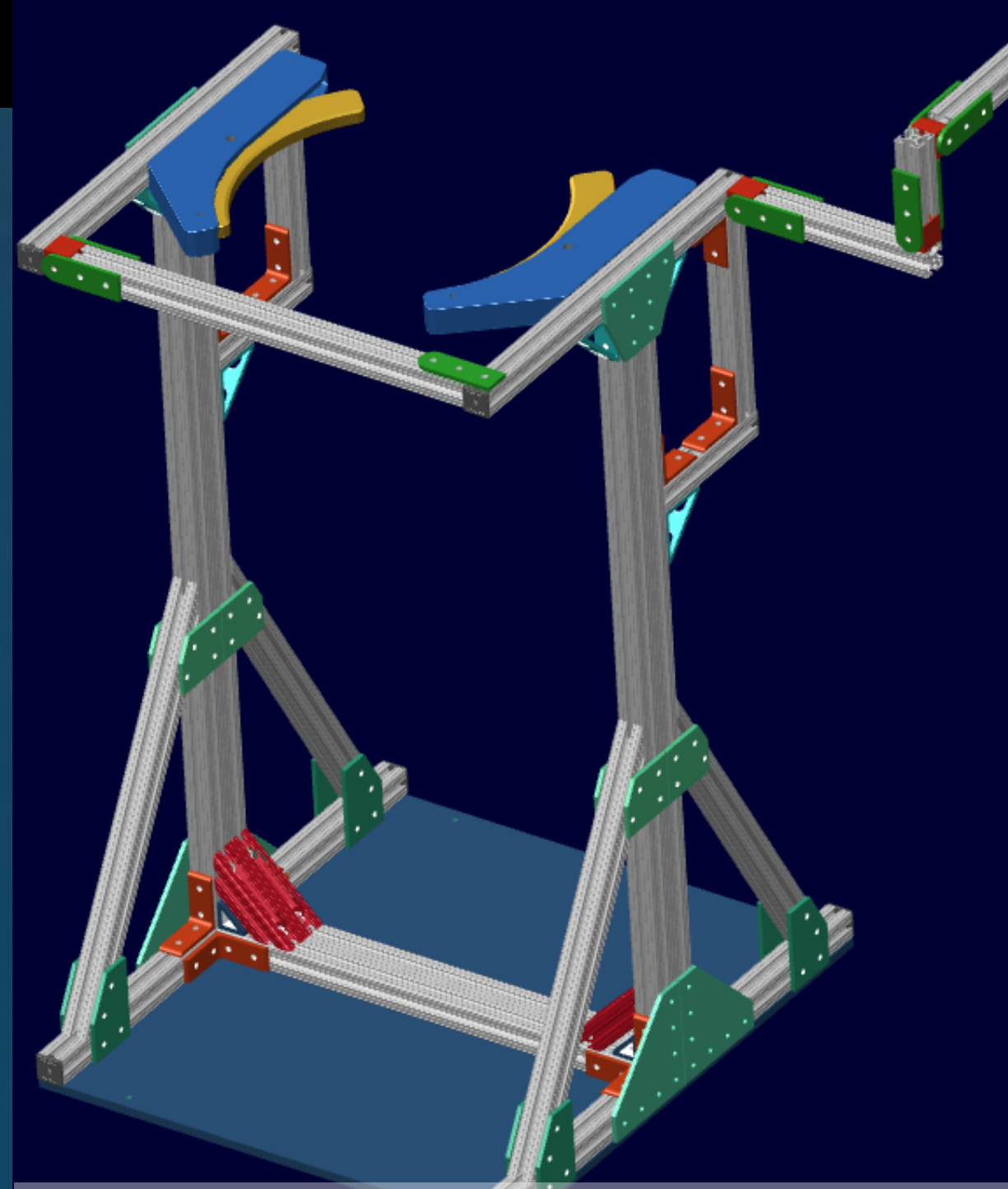
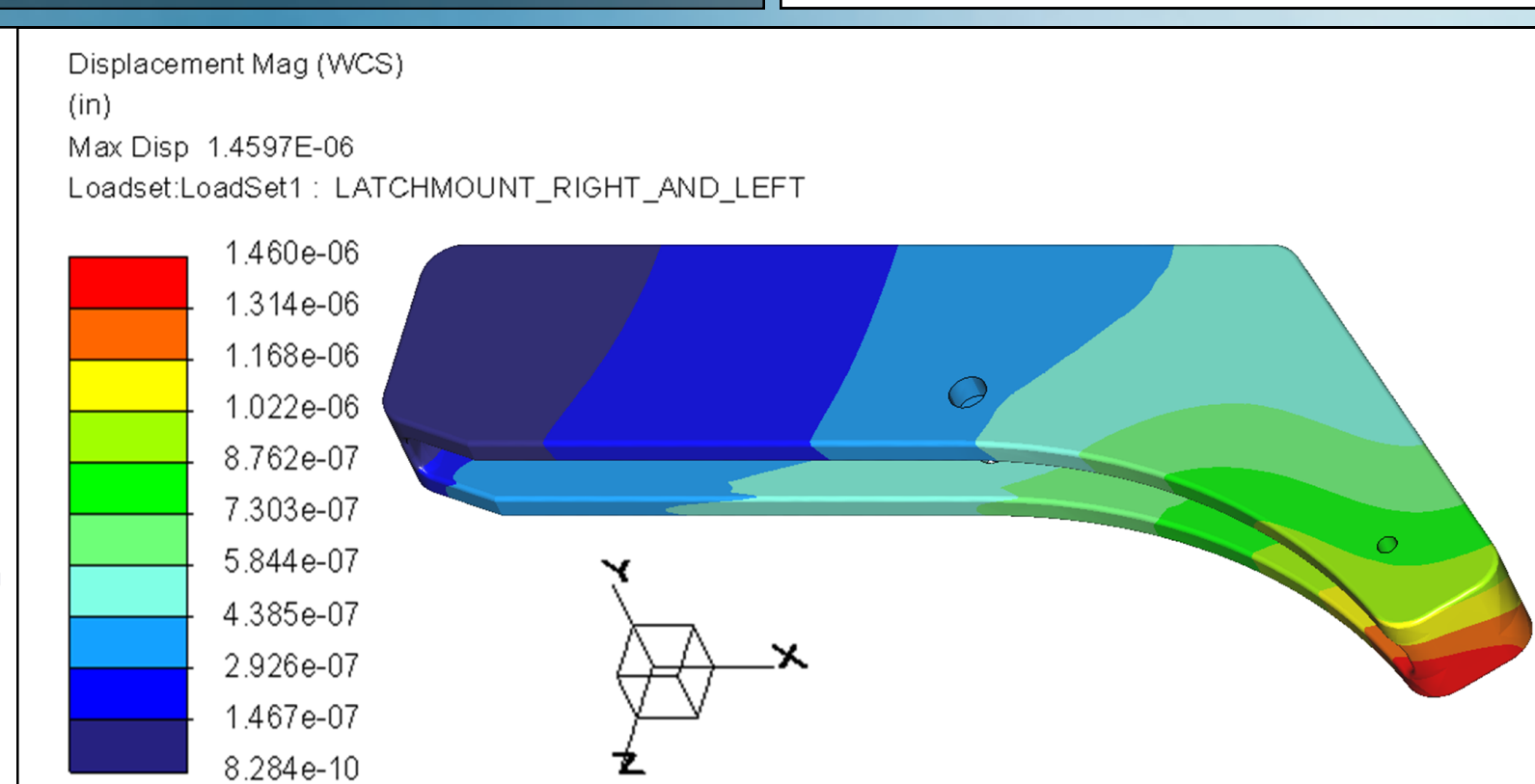
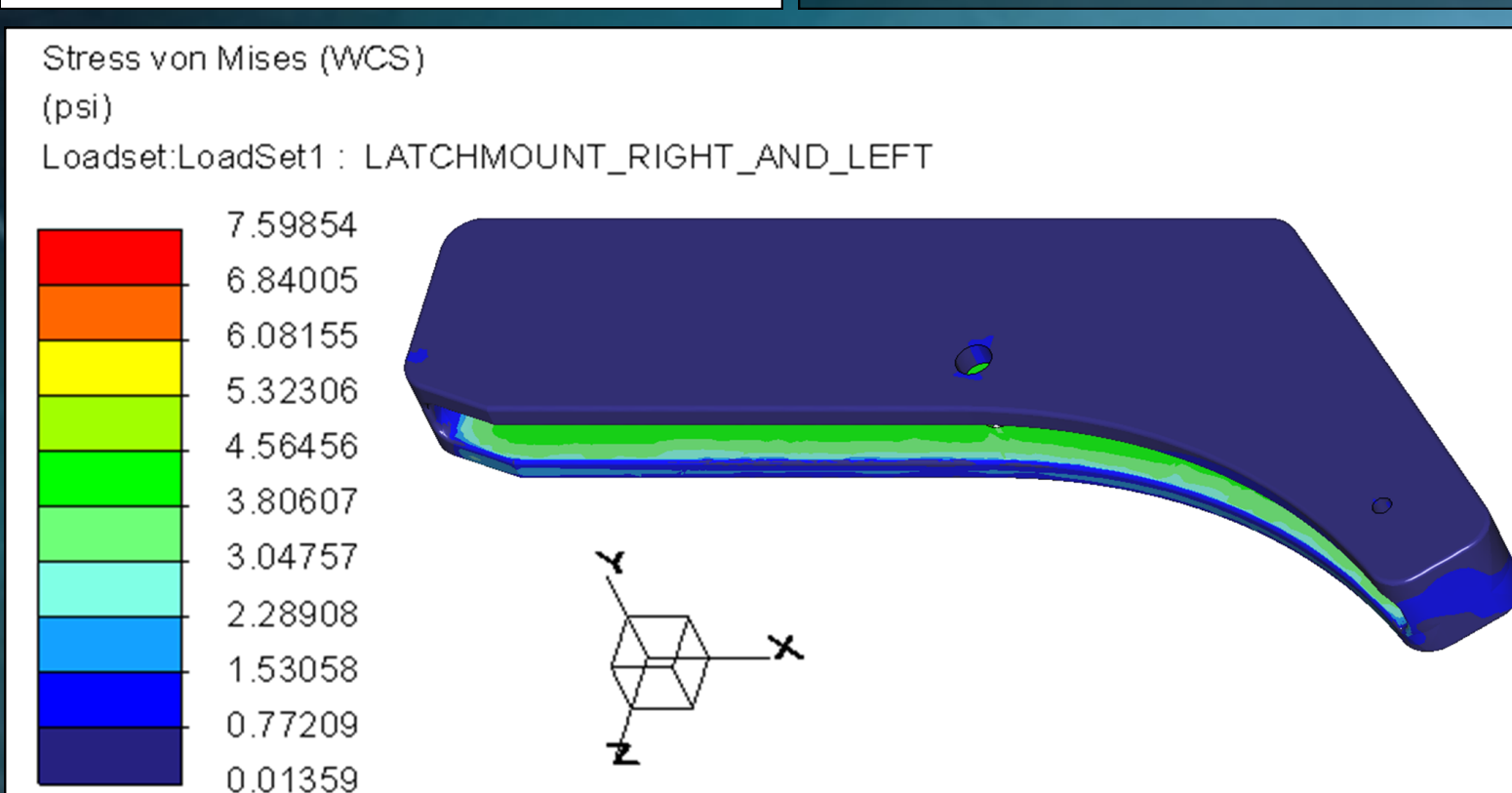
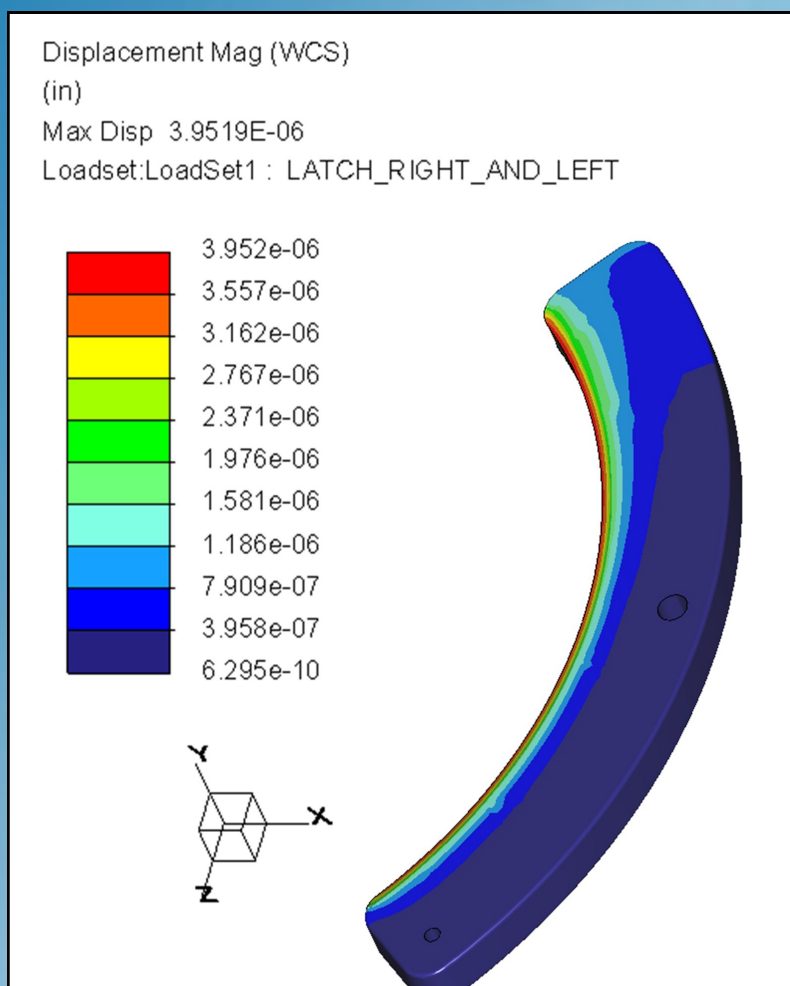
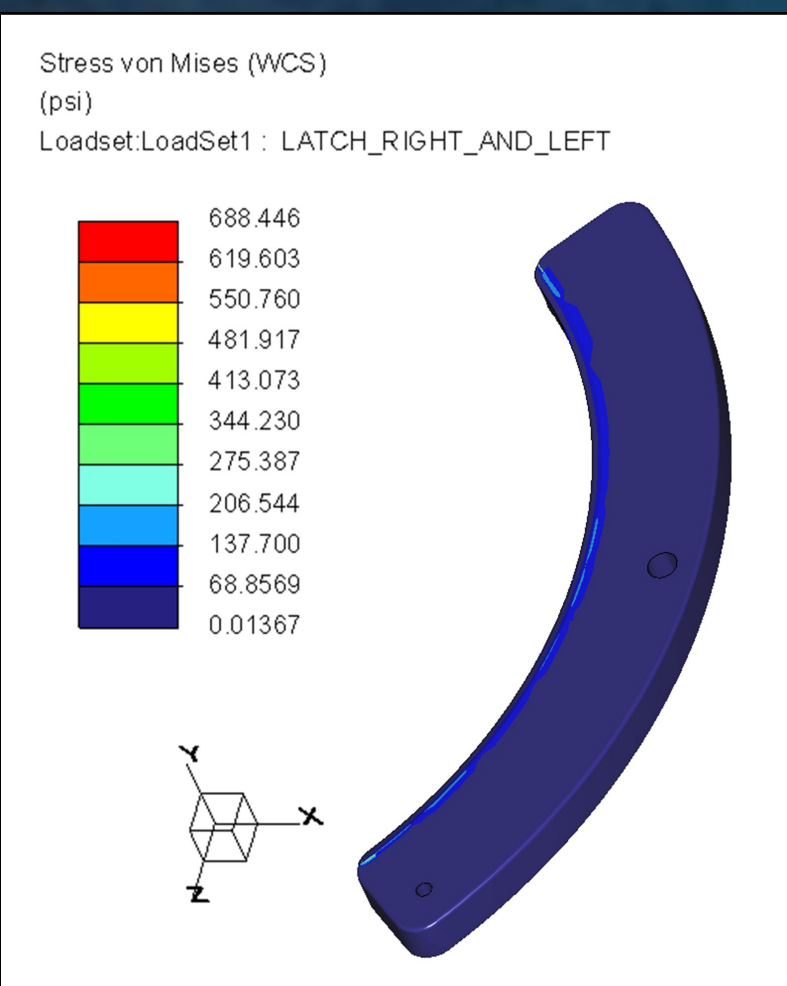


Figure 1: Creo 3D model of Z2SSS

Stress Analysis

One part of the Z2SSS is the latch mechanism interface between the suit and the stand. The mechanism consists of the latch mount and the suit latch. The suit "sits" on the latch and is locked in place with pins. It is important to consider the stress and displacement produced by the weight of the suit. The latch mechanism interface is designed by Mr. Charles Allton for the Z-2 donning stand.



Results

Stress analysis shows that the stand interface will be able to support the weight of the suit. Deflection analysis of the column supports that will mainly experience the weight of suit shows that the beams will deflect 0.0164 in. with a moment of 680 lbs-in. It is desirable to enforce the column support as much as possible, while minimizing the footprint of the inside corner support. To do so, the column supports are reinforced by installing joining plates with the 60/30 support and installing the collapsible gate support. This is done so that the technicians can have space to modify the suit legs and boots.

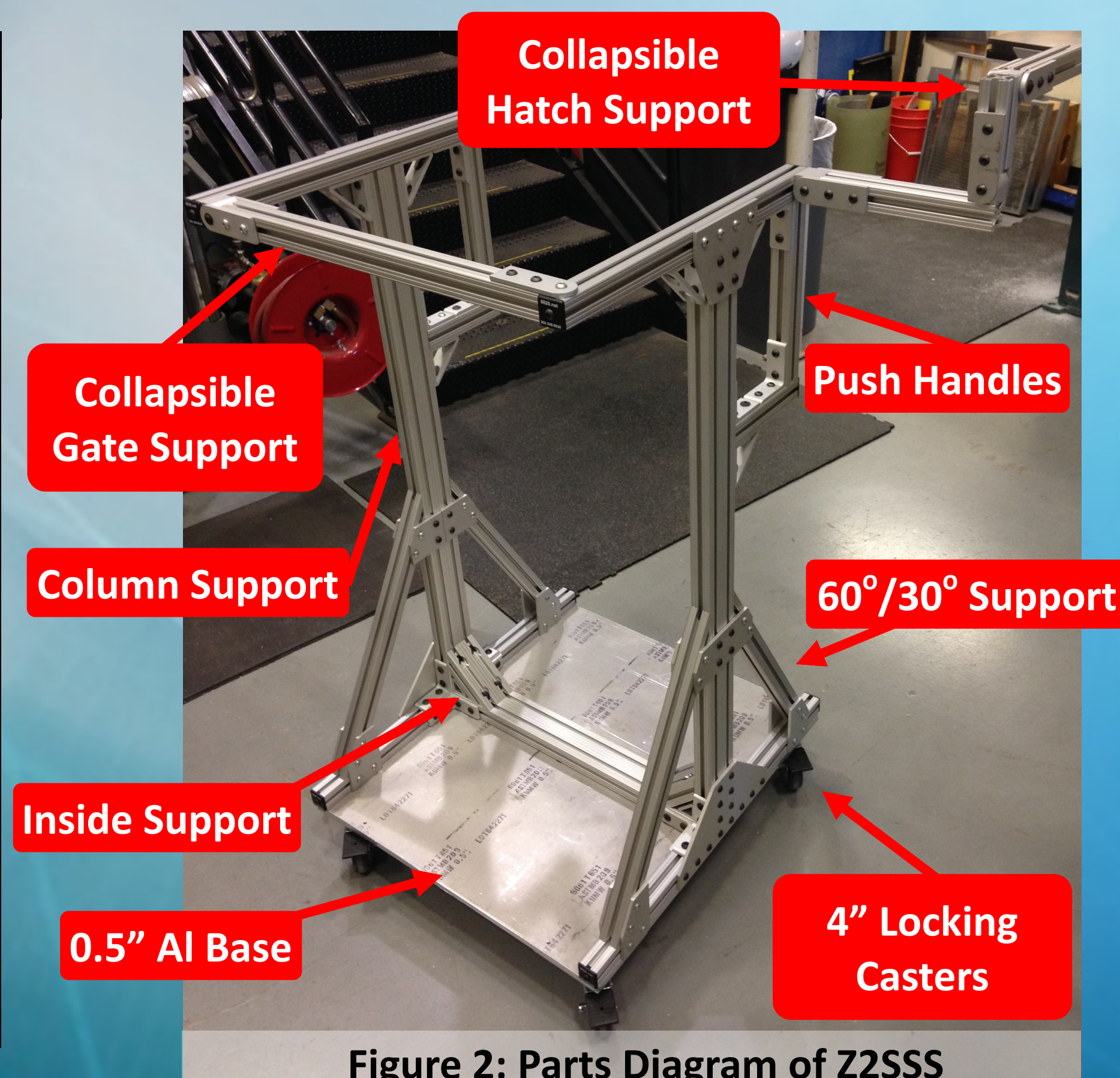


Figure 2: Parts Diagram of Z2SSS

MKIII Suit Center of Gravity Test

Introduction

It is important to consider the center of gravity (CG) of a spacesuit when developing design requirements for the next-generation of spacesuits. The closer the CG of the suit is to the CG of the crew member, the easier it will be for the crew member to balance when performing Extravehicular Activities (EVA). This in turn will conserve more energy that the crew member can use for other mission tasks or perform longer EVA's.

Currently, the process for obtaining the CG location for space suits is done through CAD models, which is not always accurate. The SSA Development team is exploring other types of physical testing to determine the location of the CG of the prototype MKIII suit. This research and testing will serve as a precursor to determine the best procedures for conducting CG testing on the Z-1 suit, Z-2 suit, the Portable Life Support System (PLSS), and other suit components.

Center of Gravity Hang Test

One method to obtain the CG location of an object is done through a hang test. The CG hang test is used in the industry for various types of rigid objects such as tanks, missiles, airplanes, cars, etc. It involves suspending the object and measuring the suspension force and the tilt angle of the object with respect to a fixed origin. The derivation of the hang test concept is presented below:

Force Diagram

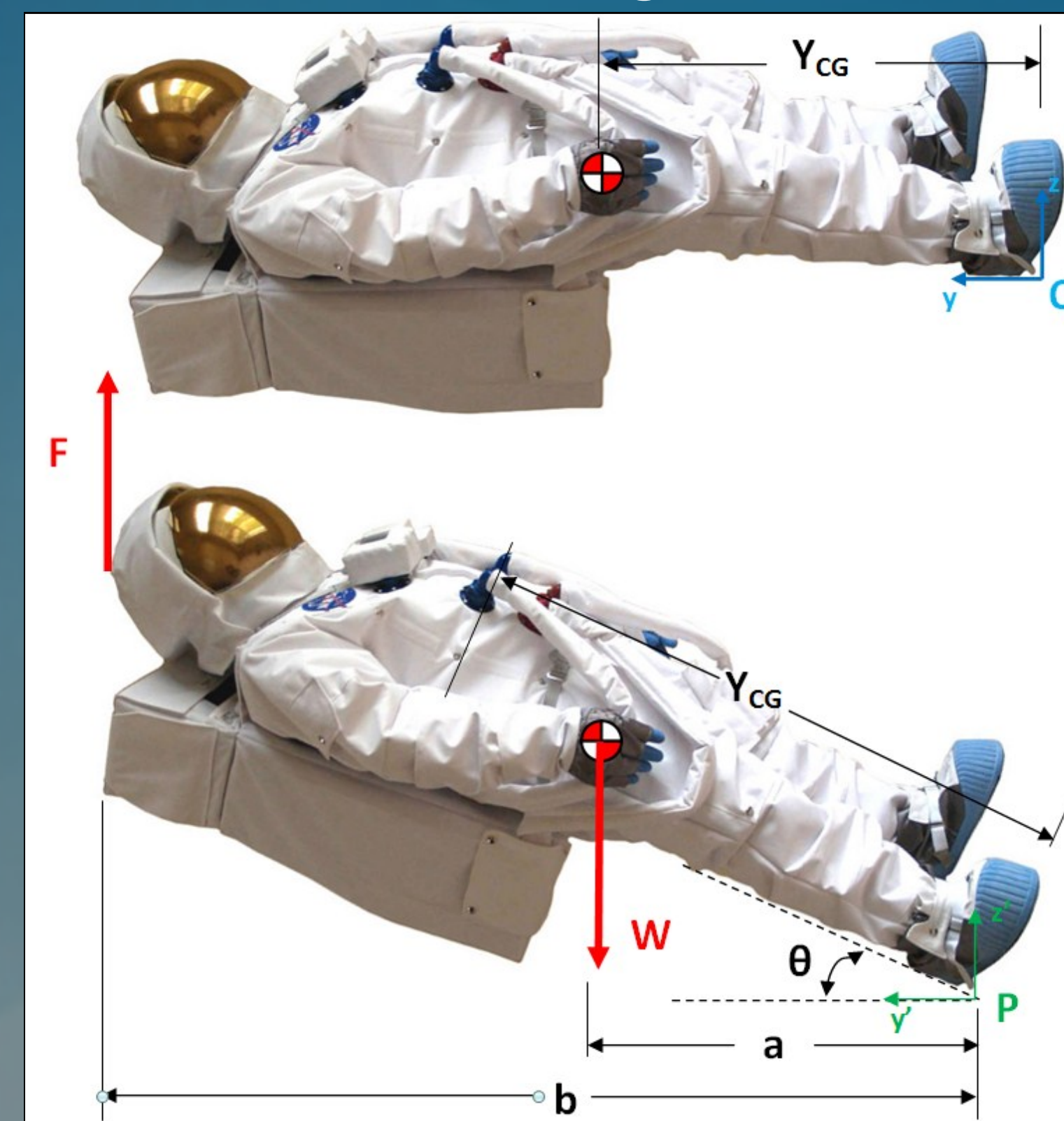


Figure 3: Force diagram of CG hang test concept

CG Calculations

We need to find YCG based on diagram:

$$Y_{CG} = a/\cos(\theta)$$

For distance a, we take the moment about the origin P (axis of rotation)

$$\sum M_P = 0$$

$$W a - F b = 0$$

$$W a = F b$$

$$a = (F b) / W$$

Therefore,

$$Y_{CG} = (F b) / [W \cos(\theta)]$$

Center of Gravity Board & Software

Another method for calculating CG location of the suit is by designing and constructing a center of gravity board. The CG board consists of four load cells at each corner, a CG acquisition software, and a non-flexing platform. The suit is placed on the platform, and then the load cells will measure the force that the suit is exerting on each one and sends the data to a DAQ computer for calculations. The CG software takes into account the location of the load cells, the size and weight of the platform, and a reference point for the X, Y, and Z CG locations of the object. With these values, a CG data report is generated through the CG software. The suit is laid down in different configurations to obtain all three dimensional location of the CG.



Figure 4: Set up of CG board & software

Conclusion

Finding the CG of a spacesuit assembly is necessary for future suit design requirements and analysis. Physical CG testing is intensive and involves a thorough set-up of equipment. Furthermore, a few points must be considered when executing these tests:

- Iteration of the CG hang test with different locations of the suspension force will produce more accurate results
- CG locations change with the configuration of the suit. Therefore, it is crucial to keep the suit in the same posture at all times. This can be achieved by a fixture or other methods of tying down the soft goods of the suit.

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"We came all this way to explore the moon, and the most important thing is that we discovered the Earth." - William A. Anders

